Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6, 1629-1634
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i6.2287

Monitoring system for electrical load usage characteristics in electrical engineering building

Andik Bintoro[1]*, Badriana[1], Zalfie Ardian[2], Teuku Multazam[1], Dahlan Abdullah[3]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Malikussaleh, Aceh, Indonesia; andik@unimal.ac.id (A.B.) badriana@unimal.ac.id (B.) multazam@unimal.ac.id (T.M.)
[2]Department of Information System, Faculty of Engineering, Universitas Malikussaleh, Aceh, Indonesia; zalfie@unimal.ac.id (Z.A.)
[3]Department of Informatics, Faculty of Engineering, Universitas Malikussaleh, Aceh, Indonesia; dahlan@unimal.ac.id (D.A.).

Abstract: Electrical energy is becoming increasingly essential for educational activities in electrical engineering facilities, as these activities include the use of electrical equipment. The quantity of electrical loads in buildings escalates annually, resulting in increased demand on existing lines and the original design of building construction. Nonetheless, the positioning and allocation of the load within the panel do not align with the augmentation of the load. Consequently, the load becomes uneven across all three stages. Phase T is experiencing an overload, while Phase R has a lesser burden compared to Phases S and T. The maximum current in Phase T is 36.3 A; the imbalance is excessive, leading to a neutral current of 25.2 A. This is perilous since the present value at the neutral point ought to be zero; if the load remains unregulated, it will lead to a contact voltage in electrical apparatus. The utilization of cables is unsuitable due to the substantial connected load, while the cable diameter is merely 2.5 mm^2, capable of conducting a maximum current of 21 A. Therefore, it is imperative to reassess the electrical installation in the engineering building to avert short circuit disruptions.
Keywords: *Current conduction capability, Electrical energy, Electrical power, Loading.*

1. Introduction

Humans need Electrical energy at this time; the energy needed to support human life is almost consumed 24 hours a day—this frequent use results in the depletion of excess and unused energy[1]. The power used by the load is recorded at the distribution station, but the load recording is not always accessible. Data recording on the kWh meter only records the overall load usage data in a place or building. The use of electrical energy can be found in the monthly account payment[2].

The electrical engineering building is a building that functions as a lecture room and at the same time a laboratory. Lecture rooms require high lighting intensity by Indonesian National Standards (SNI). Adjusting the intensity of lighting in the classroom can be one of the solutions to the use of electrical energy. The use of varying loads causes the characteristics of the load to be different from the general load.

The load fluctuates according to the discharge of the load connected from the power source. Electricity usage that sometimes exceeds normal usage results in an overrun of bill costs that must be paid every month. Monitoring the use of loads in electrical engineering buildings is expected to provide an overview of the use of electrical loads used to carry out lecture activities, both practicum and regular learning. The use of very little load results in the payment of the electricity account in the building to be large, this is due to the use of loads that are not in accordance with the usage quota, the load of the transformer must be borne by the user so that it seems as if the usage is high and the account fees that must be paid are also high.

* Correspondence: andik@unimal.ac.id

Therefore, it is necessary to conduct research on the profile of the use of electrical loads in electrical engineering laboratories, so that the expenditure of electrical energy is in accordance with the needs and uses of activities in electrical engineering laboratories.

2. Study Literature

The NodeMCU ESP8266 is a microcontroller module that utilizes the WiFi ESP8266 chip. This module was created to enhance the development of Internet of Things (IoT) projects by offering a straightforward programming interface. NodeMCU is an advancement of the ESP 8266 featuring e-Lua-based firmware[3], [4], [5], [6], [7], [8]. The NodeMCU features a micro-USB port for connectivity and power supply. Furthermore, NodeMCU is equipped with a reset and flash push button. NodeMCU employs the Lua programming language, which is a component of the ESP8266. Lua shares the same logic and structure as C, although its syntax is distinct. If you are utilizing Lua, you may employ the Lua loader or Lua uploader utility. NodeMCU, alongside the Lua language, is compatible with the Arduino IDE software, requiring just modest modifications to the board management within the IDE[9], [10], [11]. Prior to utilizing this board, it must be initially flashed to ensure compatibility with the employed tools. Utilize the Arduino IDE to implement the suitable firmware, namely the firmware provided by Ai-Thinker that is compatible with AT Command. The firmware utilized for the loader tool is the NodeMCU firmware. The graphic below depicts the NodeMCU module ESP8266.

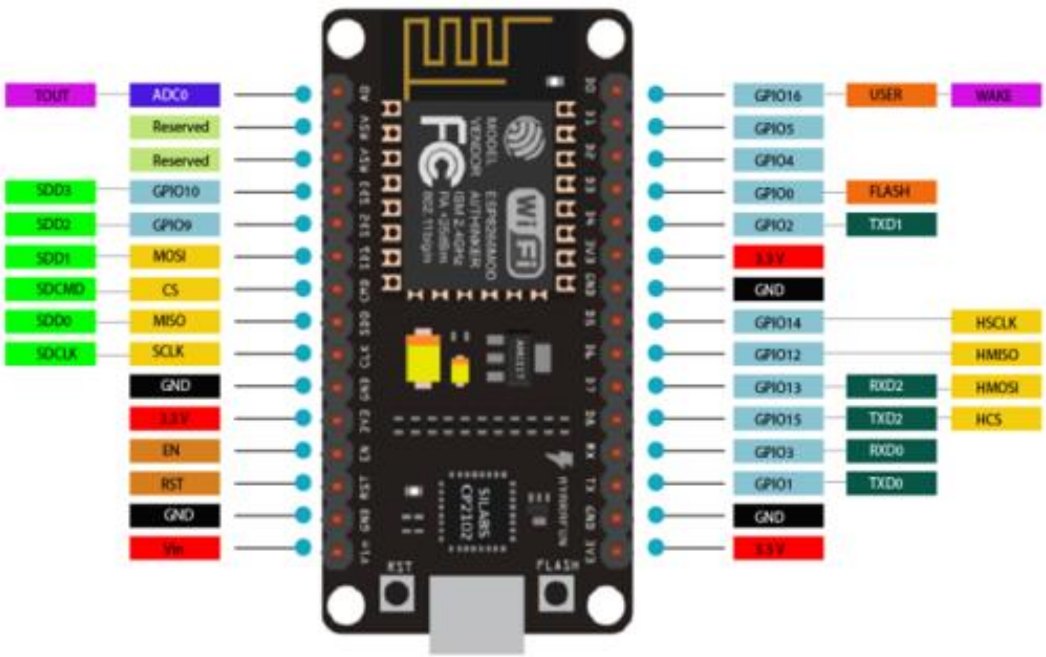

Figure 1.
GPIO node MCU.

The PZEM-004T is a sensor capable of measuring RMS voltage, RMS current, and active power, and may be interfaced with Arduino or other open-source platforms[4], [8]. The module primarily quantifies alternating current voltage, current, active power, frequency, power factor, and active energy. The module lacks a display capability; data is accessed via a TTL interface. The TTL interface of this module is passive and necessitates a 5V external power source. Consequently, for communication to occur, all four ports (5V, RX, TX, GND) must be connected; otherwise, communication is not possible.

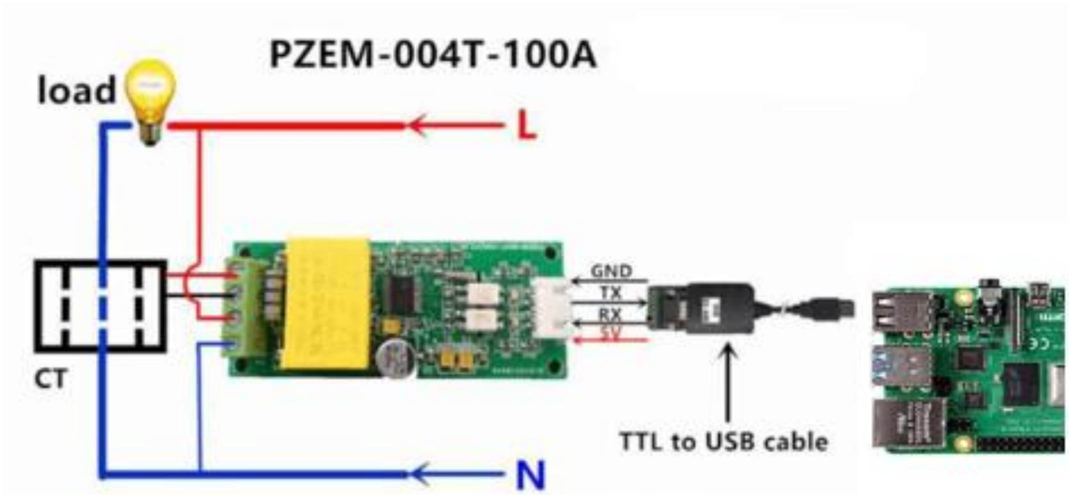

Figure 2.
PZEM-004T.

Electrical energy is required for electrical devices to operate motors, lights, heating, cooling, or to power mechanical equipment for the generation of alternative energy types[3], [4], [5]. The unit of power, defined as 1 joule per second, is often known as a watt, while the unit of energy is represented in watt-hours (Wh).

$$1 \text{ Wh} = 1 \text{ J/s x } 3600 \text{ s} = 3600 \text{ J} \quad (1)$$
$$1 \text{ KWh} = 1000 \text{ Wh} = 3600 \text{ kJ} \quad (2)$$

Electrical energy is the ability to perform or produce electrical energy (the ability required to move a charge from one point to another), denoted by W.

Electrical power is the rate of electrical energy transfer inside an electrical circuit. The SI unit of electrical power is the watt, which quantifies the flow of electrical power per unit of time (joules per second). An electric current traversing a circuit with electrical resistance generates work. Devices transform this energy into many appropriate forms, including heat (as in electric heaters), light (as in light bulbs), kinetic energy (in electric motors), and sound (in loudspeakers). Electricity can be sourced from power plants or energy storage systems, such as batteries. The product of current and effective voltage in an AC circuit is denoted in volt-amperes (VA) or kilovolt-amperes (KVA). One KVA is equivalent to 1,000 VA[7], [12], [13]. Real power, or useful power, is quantified in watts and is derived by multiplying the circuit's voltage by the power factor. A single-phase AC circuit is defined as follows:

$$P \text{ (in watts)} = V \text{ x } I \text{ x power factor} \quad (3)$$
$$\text{Power factor} = P \text{ (watts)} / V \text{ x } I \quad (4)$$

Current Conductivity or ampacity is the maximum amount of electrical current that a cable can transmit without causing an excessive temperature increase. It depends on several factors, such as the size of the conductor, the type of insulation material, the ambient temperature, and the cable installation conditions.

The cable current conduction strength standard used in low-voltage installations with a rated voltage of 450/750 V is the SNI 04-6629-2006 standard. Meanwhile, the general requirements for electrical installations in buildings are based on the load characteristics using the SNI 04-0225-2000 standard.

Table 1.
Current conductability table based on SNI.

Cable cross section (mm2)	Maximum current (Ampere)
1,5 mm^2	15 A
2,5 mm^2	21 A
4 mm^2	28 A
6 mm^2	36 A
10 mm^2	50 A
16 mm^2	68 A
25 mm^2	85 A
35 mm^2	105 A
50 mm^2	125 A

3. Methodology

The research methodology is carried out to determine whether the loading is balanced in each phase and whether the loading can withstand the cable attached to the panel. This research was carried out by measuring using measuring instruments and real-time measurements using microcontrollers. Measurements were carried out on the electrical panel box in the electrical engineering building. The load used was a mixed load, namely lighting and air conditioning lights installed on the 1st floor of the electrical engineering building.

The results of this study will be compared with the Indonesian National Standard (SNI) conductors used in load sharing on the electrical panel on the 1st floor of the electrical engineering building. This comparison of current conduction capacity is to protect the unbalanced load at each phase and prevent fire because the cable is unable to withstand the current leading to the load.

4. Result

We conduct measurements on the first-floor panel, which delineates the first-floor load from the installed load of air conditioning and lights. The installed load is a constant load present during the building's operation; the incorporation of installed equipment, such as air conditioners, constitutes an additional load, and the positioning of these air conditioners may occasionally diverge from the original electrical engineering design plan. Renovations modify the building's load, leading to a distinct load compared to the completed images. The first level of the electrical engineering building is outfitted with the following quantity of loads:

Table 2.
Current per phase on the panel.

Panel	Phase R	Phase S	Phase T	Neutral
Main	14.9 A	11.8 A	36.3 A	25.2 A
LT 1 A	7.9 A	8.2 A	1.4 A	9.0 A
LT 1 B	8.6 A	0.8 A	20.8 A	16.8 A

The measurement results indicated an unbalanced load in the three-phase electrical system of the electrical engineering building. The T phase demonstrates a greater stress than the R and S phases. Current should not flow at the neutral point; yet, imbalanced loading will result in current flow at that location. The flow of current at the neutral point renders the transformer unstable, resulting in accelerated heating.

Considering the present conduction capacity, the electrical system in the electrical engineering building employs a 2.5 mm^2 cable for load sharing and a 6 mm^2 cable for the circuit breaker input. The

ISSN: 2576-8484
Vol. 8, No. 6: 1629-1634, 2024
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LT 1 B panel remains below the maximum conduction capacity rating permitted by SNI; however, this situation warrants serious attention due to the substantial and unbalanced load sustained over extended periods during office hours from 8:00 a.m. to 5:00 p.m. Each phase expends the subsequent quantity of energy:

Table 3.
Electrical power in each phase.

Panel	Phase R	Phase S	Phase T
Main	8.335.84 W	6.601.54 W	20.308.12 W
LT 1 A	4.419.67 W	4.587.51 W	783.23 W
LT 1 B	4.811.29 W	447.56 W	11.636.61 W

The calculation findings indicate that the minimum power consumption occurs in the S phase load of the LT 1 B panel, utilizing just 447.56 watts. The primary panel's T phase utilizes a total load of 20,308.12 watts of power.

5. Conclusion

- High-power air conditioning loads should be evaluated and managed to enhance their effectiveness and efficiency in electrical power consumption.
- Unbalanced loading results in a substantial neutral current of 25.2 A. We anticipate that this will not happen, as it may result in transformer overheating and potentially hazardous electric shock at neutral.
- Assessing the cable's diameter is crucial to guarantee the building's safety, as the increased load surpasses the initial design specifications.

Acknowledgments:
The author would like to thank Malikussaleh University and LPPM Malikussaleh University for funding this research.

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